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A Simplified System of Mussel Purification

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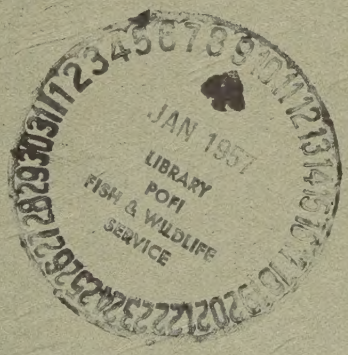
Fisheries Experiment Station
Conway, N. Wales



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A Simplified System of Mussel Purification

INTRODUCTION

n the early part of this century Dodgson (1928) devised a system of mussel purification hich has been in use at Conway in a practically unchanged form ever since. There is no oubt as to the efficacy of his method, and many years of experience have proved that urified' mussels are perfectly safe to eat raw. The object of the present work has not been increase the degree of purity achieved, but rather to see if it is possible to achieve the me degree in a manner that would involve a smaller initial capital expenditure, or need ss skilled supervision. One of the points made by Dodgson was that the purification ation should be run by an authority which was independent of fishery interests, and so eeded a full-time paid staff. This is only possible where the fishery is large, as with a small shery the income derived from a reasonable cleansing fee is not sufficient to pay the staff. here are a number of these small fisheries around our coasts which need facilities for ussel purification, and for these it is important that the method used should be a simple ne capable of being used by the fishermen themselves.

Although this work was started as part of the normal research programme, the problem f providing an installation for the Teignmouth fishery arose at an early stage. In order to vert the closing of the fishery it was imperative to find a solution to the problem within a w months; this had a very stimulating effect on the research in so far as the sense of rgency led to the rapid development of the new methods on a commercial scale. On the her hand, because of this urgency, it was not possible to explore fully many of the ndamental aspects of the processes involved. This account describes the development and tablishment of the Teignmouth mussel tanks, together with the results of the first ason's operations, but leaves unanswered many questions that will be explored in more tail later.

BACTERIOLOGICAL METHODS

Mussels were examined by the method of Clegg and Sherwood (1947), the roll tubes eing incubated at 44°C. During the course of the work minor modifications were intro- uced; on January 1, 1953 the inoculum was increased from 1 ml. to 2 ml. to make the st more sensitive. In September, 1953, when an Astell rolling machine came into use, two ottles containing 5 ml. of medium were each inoculated with 1 ml. of reconstituted mussel n place of the one tube of 10 ml. of medium previously used. At this time the gelatine was mitted from the medium as it was found to be unnecessary with the Astell bottles.

In accordance with the recommendations of Clegg and Sherwood, ten mussels were ken for a sample; if unpurified they were examined as a pool, if purified they were also xamined individually. The results are expressed as numbers of faecal *Bacterium coli* per ml. f flesh.

All water examinations were done by a modified Clegg and Sherwood technique. For ach sample five roll bottles were each inoculated with 2 ml. of the water being examined, hese were incubated overnight at 44°C. The total count of red colonies gave a direct eading of the numbers of faecal *Bact. coli* per 10 ml. of water. This method will be iscussed more fully in a later paper, but the following comments are relevant. Clegg and herwood showed that the roll tube method gives more consistent results than the 'Most robable Number' liquid method. Because of the great variation in the results obtained

with the latter, it is not possible to relate the results obtained by one method at all cl to those obtained by the other. Many mussel samples have been examined at Co using both methods on the same sample and, in general, it has been found that w the inoculum contained 5 or less *Bact. coli*, they were more likely to be detected by the tube method; with moderate numbers the two methods gave similar results; and with counts the 'Most Probable Number' usually gave a higher result than the roll tubes.

THE SOURCE OF MUSSELS USED IN EXPERIMENTS AT CONWAY

A Survey of the Teign estuary had shown that at least some of the mussels were he polluted, figures of over 100 *Bact. coli* per ml. of flesh being obtained. For this reason it decided not to use mussels brought for purification to the Conway tanks as they rarely s a comparable degree of pollution. The mussels used were taken from the junction o Gyffin stream and the Conway river, where they can be relied upon to show high pollu Continued collection from a small area had certain serious disadvantages, however, to prevent the area from being denuded in a short time it was necessary to return mu to the bed, after they had been used, for re-pollution. As the area was being contin trampled some of the mussels became half buried, and it was suspected that when t were gathered later they were in a semi-moribund state and did not function prop To overcome this difficulty a polluting station was set up. Trays were arranged on w the mussels could be placed near to the low water mark of ordinary tides. On these t they were held clear of the mud and could pick up a good degree of pollution and remain healthy without any risk of being trodden into the ground. This device also m the work of collecting material for the experiments very much easier. After use the mu were returned to the trays and allowed to stay there for at least a week before they again used. After this system had been adopted (Expt. 37) there was a reduction in number of odd high counts obtained from the purified mussels. There is little doubt the repeated use of the same material put the proposed purification system to a more se test than it would get in practice, using mussels from undisturbed beds on each occa

EXPERIMENTAL WORK

Since filter feeding molluscs remove solid particles from the water around them, d some and pass the rest out as either faeces or pseudo-faeces, one might expect that would in time remove the bacteria from a limited volume of water and thus make it enough for them to cleanse themselves in it. This has been shown by Cole (1954) to b case for oysters stored in pits. The present account describes the investigation of method for mussels. In approaching a problem of this type one can either take the exis process as the starting point and explore the possibilities of simplifying it, or start the simplest possible apparatus and add refinements to the method as they are found t necessary. It was considered that the second method would yield the required results rapidly. Mussels were placed in a container on the foreshore which was so situated th was covered by spring tides but not by neap tides, so that it was possible to follow changes in pollution that occurred when the water was renewed by each tide and also the water remained unchanged for four or five days. This container was the bow se of the wreck of an iron ship that lay on the foreshore; it made a roughly triangular about 3 ft. wide at one end, 4 ft. long, and 2-3 ft. deep. The accumulated water and were removed, and it was roughly washed out, but no disinfectant was used.

In the first experiment three bucketfuls of mussels were placed in the bottom. night the tide came over and filled the tank, but as the neaps were approaching, the tide did not again reach the top of the tank for five days. A sample of the mussels examined bacteriologically at the start of the experiment, and after 1, 2, 3, 5, 6 and 7 n (Exp. 1). It will be seen (Table 1) that initially the mussels were polluted on an ave

Table 1: *Preliminary experiments in the container on the seashore*

Experiment No.	Date	Counts of faecal *Bact. coli* per ml. of flesh in Mussels											Treatment
		Before treatment	After treatment										
			Individuals									Pool	
1	27 Aug. 52	268	0	286	2	0	2	0	0	0	0	16	1 night
		268	12	4	2	2	0	2	2	6	4	1	2 nights, water unchanged
		268	0	0	0	0	4	2	0	0	0	2	3 nights, water unchanged
		268	0	0	0	0	0	0	0	0	0	0	5 nights, water unchanged
		268	30	4	28	18	32	6	34	20	26	21	6 nights, tide came over in night
		268	0	4	2	0	0	0	0	0	0	3	7 nights, tide came over again
2	3 Sep. 52	102	2	34	4	8	0	0	2	14	8	11	1 night, flooded by each tide
		102	6	12	4	14	30	4	32	8	6	15	2 nights, flooded by each tide
		102	0	0	0	12	0	4	6	0	4	7	3 nights, flooded by each tide
		102	8	10	10	40	12	26	2	18	28	19	5 nights, flooded by each tide
3	10 Sep. 52	167	0	4	8	0	4	12	12	12	12	10	1 night, water unchanged
		167	4	4	0	0	1	6	1	0	6	5	2 nights, water unchanged
		167	2	4	0	0	0	0	2	0	2	1	3 nights, water unchanged
4	12 Sep. 52	197	10	10	12	8	4	14	4	2	14	10	2 nights, same water as in Expt. 3
		197	8	12	4	2	8	12	8	134	2	78	3 nights, same water as in Expt. 3
5	16 Sep. 52	203	138	22	36	20	14	164	554	28	30	139	1 night, same water as in Expt. 3
		203	78	76	194	156	206	52	56	18	718	141	2 nights, same water as in Expt. 3

the extent of 268 *Bact. coli* per ml. of flesh; after one night one mussel showed 286 per ml., ut the rest were clean, that is contained less than 5 *Bact. coli* per ml. of flesh. The samples ken after 2, 3 and 5 nights were, in general, clean. Then the tide started to flood the tank gain and the mussels became re-polluted to a moderate extent. During the period when the nk was covered by each tide, the mussels evidently did not have time to clean the water

and then themselves before the next tide. This was confirmed in the next experiment m
during the period of spring tides (Expt. 2), when the tank was covered by every high t
Again three bucketfuls of polluted mussels were used, and samples were taken at the s
and after 1, 2, 3 and 5 nights. In this case the initial pollution was 102 per ml., and a
one night it was reduced to 11 per ml., two nights 15 per ml., three nights 7 per ml.,

Table 2: *Experiments in a tank to determine the amount of preliminary washing necessary*

Experiment No.	Date	Counts of faecal *Bact. coli* per ml. of flesh in Mussels												Treatment
		Before treatment	After treatment											
			Individuals										Pool	
6	26 Sep. 52	107	0	0	0	2	4	0	0	0	2	0	1	No grids. Mussels crudely gathered in clumps. Preliminary bath, then 2 nights.
7	29 Sep. 52	22	26	2	10	22	22	4	0	0	4	14	—	No grids, crudely gathered in clumps with all mud. 1 night and 3 nights.
		22	42	58	28	8	28	2	32	10	16	12	32	
8	4 Oct. 52	89	0	0	0	2	0	0	0	0	0	2	1	No grids, crudely gathered, washed in baskets in sea. 3 nights.
9	8 Oct. 52	119	2	0	2	0	4	2	2	4	10	0	2	As No. 8.

re nights 19 per ml. This experiment showed that with this relatively polluted water pply the mussels need a longer period than that between two tides in which to purify th the water and themselves. In this experiment the mussel samples were collected ortly before the rising tide covered the tank, i.e. about 10 hours after the previous tide d left it.

The next experiment was intended to provide further evidence as to the effectiveness such a crude method of purification. The water in the tank was siphoned out, but the cumulated mud and mussel faeces of the previous experiments were left. Three bucketfuls mussels were used and the experiment so timed that after the first filling the tank was t again covered by the tide during the experiment. The initial pollution of the mussels as 167 per ml., and after one night this was reduced to 10, two nights 5, and three nights per ml. Again, in spite of the mud in the tank, satisfactory purification was achieved in ree nights (Expt. 3).

The next two experiments (4 and 5) were designed to show whether water which had en used to purify mussels could be used again without special treatment. The water of e previous experiment was used, the old mussels being raked out and a fresh lot put in. fter three nights the pollution was reduced from 197 to 39 per ml., a reduction, but in way a purification. The mussels were removed, and a third lot put into the water. In this se the pollution was reduced from 203 to 141 per ml. in two nights, and then the rising des brought the experiments to an end. It was evident, however, that a fresh lot of water as needed for each batch of mussels.

In order to control the experimental conditions the work was transferred at this stage concrete tanks. These were about 12 ft. square by 3 ft. deep, and were fitted with grid sts, penstock channel and gutter, as in the commercial mussel purification tanks. Usually bout two cwt. of mussels were used in each experiment, and the depth of water used was djusted to give an approximate mussel/water ratio of one per quart. Having established at the water need not be sterilised or the tank cleaned between batches, the next point settle was the extent to which the mussels need to be cleaned externally before they are urified. In Experiment 6 the mussels were gathered in clumps and spread in the tank. hey were covered with water which was run off after a few minutes carrying away some f the mud. They were then given a 48 hour treatment at the end of which they were clean Table 2). In Experiment 7 the extreme limit of dirt was left on them, they were gathered clumps with all the mud, including the particularly black mud that lies below the surface. articular care was taken not to break up the mussel clumps or to lose any of their adhering ud. They were spread on the floor of the tank in a layer 1 to 2 in. thick, and covered ith 18 in. of water. After three nights under these conditions they were just as polluted s they had been at the start (Table 2). The reason for this was not explored. The black ud has a very high oxygen demand and it is likely that it removed the oxygen from the ater and thus prevented the mussels from functioning. The next two lots were given imilar treatment, except that, after the clumps of mussels had been gathered into baskets, ey were swished round in the sea to remove some of the mud (Expts. 8 and 9). These urified satisfactorily, although the outsides of the shells were still muddy.

Three experiments (10, 11, 12, Table 3) followed in which the effect of using grids was xamined. Purification was equally successful whether or not the mussels were placed on rids. Variations in the thickness of the layer of mussels were also tried. It was soon found hat there was no difference between a layer one mussel thick and one 3 in. thick, and ttention was concentrated on the relative merits of 3 in. and 6 in. layers. An analysis of he results of Experiments 30-34 (Table 4), in which the mussels are classified according whether they contained 0, 1-5, 6-10 or over 10 *Bact. coli* per ml. of flesh, gives the llowing result:

	0	1-5	6-10	10+	*Total*
3 *in. layer* ..	16	27	1	5	49
6 *in. layer* ..	18	17	11	4	50

The numbers of mussels having 0 *Bact. coli* per ml. of flesh are virtually the same with he 3 in. and 6 in. layers, as are those having over 10; it is in the 1-5 and 6-10 groups hat a difference occurs. This difference favours the use of a 3 in. layer, but it is not a great

difference and in view of the small number of experiments is probably of little significan
A 6 in. layer is more difficult to hose, and a good pressure (150 lb./sq. in.) of wate
needed to do it efficiently, especially if there is a considerable amount of mud on
mussels.

Table 3: *Experiments with and without grids*

(Water pollution is given as the count of faecal *Bact. coli* per 10 ml. in this and following tables)

Experiment No.	Date	Water Initial Pollution	Water Final Pollution	Counts of faecal *Bact. coli* per ml. of flesh in Mussels								Treatment	
				Before treatment	After treatment								
					Individuals						Pool		
10	29 Oct. 52	15	3	17	0	0	0	0	0		1	1 mussel thick	No grids
	29 Oct. 52	15	3	17	0	0	0	0	0		1	3 in. thick	
	29 Oct. 52	15	3	17	4	4	0	0	0		1	6 in. thick	
	29 Oct. 52	15	3	17	0	6	0	0	0		2	1 mussel thick	Grids
	29 Oct. 52	15	3	17	0	2	0	0	2		1	3 in. thick	
	29 Oct. 52	15	3	17	0	2	0	0	0		1	6 in. thick	
11	6 Nov. 52	—	—	21	0	0	0	12	0	0	4	0	0	1	No grids	6 in. thick
	6 Nov. 52			21	2	2	2	2	0	0	0	2	0	1	Grids	
12	12 Nov. 52	—	—	35	0	2	0	2	0	22	0	0	8	5	No grids	6 in. thick
	12 Nov. 52			35	0	6	0	0	4	2	2	2	0	5	Grids	

Some experiments were done at low temperatures (1-4°C.) to find out whether the method would work under such conditions. They were done in a cold chamber to facilitate temperature control, in February when the mussels were acclimatised to cold in their natural habitat. In each experiment ten mussels were placed in ten litres of water for

Table 4: *Experiments with the mussels laid 3 in. and 6 in. deep*

Experiment No.	Date	Water Initial Pollution	Water Final Pollution	Counts of faecal *Bact. coli* per ml. of flesh in Mussels												Treatment
				Before treatment	After treatment										Pool	
					Individuals											
					6 in. layer. Two lots of about 1 cwt. each											
28	17 Nov. 52	14	4	46	6	2	2	0	2	2	4	16	0	10	5	Hosed before and after, water leaked down to top of mussels. 2 nights.
			4	46	0	0	0	0	2	0	0	0	4	0	4	
29	19 Nov. 52	18	2	47	2	0	4	2	0	4	16	0	16	0	5	Hosed before and after. 2 nights.
			2	47	2	0	0	0	0	6	6	6	6	2	2	
					Comparison of 6 in. and 3 in. layers											
30	24 Nov. 52	53	2	59	0	0	0	0	0	4	2	2	2	0	1	3 in. layer (½ cwt.) } 2 nights.
		53	7	59	8	4	0	0	2	0	0	6	2	10	3	6 in. layer (1 cwt.) }
31	1 Dec. 52	120	45	53	0	8	2	12	2	56	4	0	2	2	9	3 in. layer.
		120	2	53	14	2	0	6	2	6	8	2	4	0	3	6 in. layer. Water leaked during first night. Replaced next day for second night.
32	4 Dec. 52	26	1	23	4	0	2	4	2	0	4	2	4	0	1	3 in. layer } 2 nights.
		26	0	23	0	0	0	2	0	6	8	0	0	0	3	6 in. layer }
33	8 Dec. 52	12	5	88	2	2	4	0	0	0	0	2	0	0	1	3 in. layer } 2 nights.
		12	2	88	8	0	4	0	0	0	0	2	2	2	1	6 in. layer }
34	10 Dec. 52	86	22	20	2	14	16	2	2	2	1	42	4	2	7	3 in. layer } 2 nights. Mussels from sand bar; perhaps partly choked.
		86	18	20	2	4	4	24	56	10	6	12	2	4	11	6 in. layer }

48 hours. The results of seven experiments are given in Table 5. In these experime the initial water pollution ranged from 38 to 580 *Bact. coli* per 10 ml. In every case pollution of the water was substantially reduced by the functioning of the mussels where the initial water pollution was relatively low, as in the last experiment, satisfact purification of the mussels occurred. Even at 1°C. the method would work provided initial pollution of the water was not more than about 30 *Bact. coli* per 10 ml.

Table 5: *Experiments at low temperatures*

Temp.	Initial Water Pollution	Final Water Pollution	Counts of faecal *Bact. coli* per ml. of flesh in Mussels										
			Before treatment	After treatment									
				Individuals									Poo
4°C.	456	15	16	32	1	1	15	3	8	5	7	4	4	6
2°C.	445	17	22	12	15	36	51	57	23	29	21	14	14	32
2°C.	580	13	30	8	16	18	16	10	9	23	7	20	16	49
2°C.	328	47	12	56	39	67	40	46	37	39	41	55	33	55
1°C.	101	0	5	0	2	1	2	1	1	4	3	2	3	2
1°C.	78	3	8	0	5	1	6	1	1	2	1	2	1	3
1°C.	38	1	38	0	3	0	1	0	0	2	0	0	0	2

REVIEW OF RESULTS

At this stage it was felt that sufficient knowledge had been gained for a picture of the process to be formulated, and this is a convenient point at which to discuss the m findings.

(a) Flushing the Tank

That mussels could remove the polluting bacteria from a limited volume of water and purify themselves had already been established by Dodgson (1928), who also showed bacteria imprisoned within mussel faeces do not normally escape into the water. It see likely, however, that if the mud and faeces, left in the tank by one lot of mussels, violently stirred up during the process of removing the mussels and re-filling the t then the faeces might be sufficiently broken to liberate large numbers of polluting bact and perhaps waste products from the metabolism of the mussels which might inhibit t functioning. Experiment 3 was designed to examine this possibility but, although it obvious that the faeces were considerably broken up when the mussels were raked ou the tank, the next lot of mussels functioned just as well as did the first lot. The clearly no need to remove the faeces of one lot of mussels before the next batch is trea This point is of some importance in view of the great care taken when flushing the t in the Dodgson process.

(b) External Washing of the Mussels

It was found that, provided the black de-oxygenated mud from below the surface was included, mud on the mussels did not interfere with purification. The mud mus removed at some stage to make them attractive for market, and if this can be done be

ney come into the tank the need for a sloping floor and penstock apparatus to flush the ank is greatly reduced. It is necessary to separate the mussels from their faeces at the end f the purification process and this can be done conveniently by hosing on grids. If the nussels are externally clean before they are placed in the tank this final hosing is the only ne that is necessary. This separation may alternatively be carried out by lifting the mussels ut of the tank or pit by means of a didal (Cole, 1954, p. 4), or similar instrument, while here is still water in the tank.

(c) The Use of Grids

The present writer has been unable to find any statement in Dodgson (1928) giving the eason why grids were used although it is clear that they assist the hosing process. The xperiments with and without grids were intended to find out whether they had any unction apart from assisting hosing. It was possible that the free access of water to both ides of a layer of mussels supported on grids might make purification more effective than t would be with mussels resting directly on a solid surface. Also the fact that at least ome of the faeces extruded by the mussels fall through the grids and are thus removed 2 or 3 in. from the mussels might have been an advantage. In fact the presence or absence f grids was found to make no difference to the purification process, and their only function s to help the final hosing. It is for this purpose that they are now recommended unless he use of a didal or some similar device is preferred.

(d) Thickness of the Layer of Mussels

One may ask why there should be a limit to the thickness of the layer of mussels. There are wo reasons: (1) the mussels in the middle of a very thick layer can only receive the water hat has passed through, and been de-oxygenated by, those surrounding them, and in onsequence they are unable to function; (2) as the thickness increases effective hosing ecomes more and more difficult. The results of the experiments are not conclusive. It is lear that a 3 in. layer is satisfactory, while more information is desirable before the use f a 6 in. layer can be recommended. It seems unlikely that a much thicker layer could e used.

(e) Re-use of Water, and Quantity Required

The water used for one lot of mussels cannot be used for subsequent lots unless it is e-aerated.

In the Conway mussel tanks approximately one quart of water is provided for each nussel (i.e. water depth 3 ft.), and in general the same ratio has been adhered to in this ork. Experience over many years has shown that this quantity is sufficient to keep mussels n good condition, that is without gaping, over two days (Saturday to Monday) at all times n the usual mussel season. Since water is normally in plentiful supply there was no point n experimenting with smaller quantities in the early stages. Later it was found that the Teignmouth tank had to be limited to 2 ft. in depth because of the nature of the foun- lation, and a few experiments (43 to 52) were done with this lower water/mussel ratio t temperatures of 4°-7°C. These gave satisfactory results. At that time the full implications f the effect of raising the water temperature were not appreciated. Gray (1928) gives igures for the rate of functioning of mussels, as measured by ciliary action, at various emperatures, and Harvey (1928) gives values for the volume of oxygen contained in fully erated sea water of Sp. Gr. 1.0262 (19 gms. Cl. per 1,000 gms.) at similar temperatures. The length of time mussels can continue to function in a finite volume of water will depend n both the rate of functioning and on the amount of oxygen available, and if we divide he one into the other we get a figure which, other factors being kept the same, is related o the duration of functioning at that temperature. Such values for temperatures from ° to 25°C. are given in the following table.

Table 6: *The effect of varying temperature on the duration of functioning of mussels in a limited volume of water*

Temp. °C.	Rate of functioning	0_2 content	$\frac{0_2 \text{ content}}{\text{Rate of functioning}}$
0	0·08	8·08	100
5	0·15	7·16	48
10	0·26	6·44	25
15	0·40	5·86	14·6
20	0·60	5·38	9
25	0·86	4·95	5·6

The last column shows clearly the effect of raising the temperature on the duratic functioning. In round terms, from 0°-15°C. each rise of 5°C. halves the duration; quantity of water sufficient to last for four days at 0°C. will last for only one day at 10° half a day at 15°C. For a layer of mussels 3 in. thick to function for 48 hours, a dep water of 3 ft. is necessary in the warmer parts of the season, when temperatures are ar 15°C.; this quantity may be reduced when temperatures are lower.

(f) Initial Pollution of the Water

In a method where the mussels remain for two or three days in unchanged water one n expect a limit to the permissible degree of initial pollution of the water. The numb bacteria removed from the water is controlled by the rate and duration of functioni the mussels, which, in turn, is limited by the total oxygen supply available, sinc oxygenation of the water from the atmosphere does not keep pace with its use b mussels. A thorough investigation of this question would need a series of experin using different degrees of initial water pollution at temperatures from 0°C. to 2 Because of the urgency of providing a method for use at Teignmouth this question wa fully explored, but a series of low temperature experiments was done as it was th that at temperatures approaching 0°C. slow functioning might prevent purification. results (Table 5) show that at 1°C., with an initial water pollution of 38 *Bact. coli* per 1 purification was satisfactory, while with higher initial water pollutions satisfactory fication did not occur. Apart from these low temperature experiments, the highest i water pollution which gave satisfactory results was 53 *Bact. coli* per 10 ml. of wat Experiment 30. Analyses of the water at Teignmouth showed that there would b difficulty in getting water with 5 or less *Bact. coli* per 10 ml. so that there would be an a margin of safety at the site.

Mussel purification may thus be reduced to washing the mussels, placing them layer 3 in. thick in a tank and covering them with 3 ft. of clean or lightly polluted for a period of two to three days. At the end of this period they may either be lifte with a didal or, if they are on grids, the water may be run off and the mussels sho up after being hosed.

PILOT PURIFICATIONS

The main features of a simplified system having been established, it was decided t a set of pilot purifications at Conway, each using about half a cwt. of mussels, empl the technique that it was intended to adopt later on a commercial scale. In experiments the mussels were placed on grids after being picked over to free them

Table 7: *Pilot purifications*

Experiment No.	Date	Water temp.	Water Initial Pollution	Water Final Pollution	Counts of faecal *Bact. coli* per ml. of flesh in Mussels			Treatment
					Before treatment	After treatment		
						Individuals	Pool	
35	5 Jan. 53		6	1	71	1 0 10 0 2 1 0 0 0 1	1	3 in. layer, 2 nights.
36	7 Jan. 53	5°C.	25	1	33	1 0 0 1 3 0 1 0 0 0	2	
37	12 Jan. 53	6°C.	9	1	89	0 1 5 3 5 0 0 0 2 4	2	
38	14 Jan. 53	6°C.	11	1	177	4 0 1 1 1 7 10 0 1 3	1	
						Expt. 39 was abandoned		
40	20 Jan. 53	5°C.	0	0	17	1 0 0 0 0 0 0 0 0 1	0	3 in. layer, 3 nights.
41	23 Jan. 53	6°C.	2	0	131	0 1 3 3 2 1 1 3 0 0	1	
42	27 Jan. 53	6°C.	0	1	129	5 4 2 5 5 3 1 0 0 4	3	6 in. layer, 3 nights.
43	30 Jan. 53	7°C.	14	0	45	0 0 0 0 0 0 1 1 2 2	0	3 in. layer, 3 nights.
44	3 Feb. 53	5°C.	1	–	23	0 0 0 0 0 0 0 0 1 1	0	
45	6 Feb. 53	5°C.	0	0	41	0 0 0 0 1 1 1 1 1 2	0	Water depth 1 ft. only, equivalent to 2 ft. in Teignmouth tank.
46	9 Feb. 53	4°C.	9	0	51	0 0 0 0 0 0 1 1 1 2	0	
47	13 Feb. 53	4°C.	0	0	23	0 0 0 0 0 0 0 0 1 2	1	
48	17 Feb. 53	5°C.	12	3	8	0 0 0 1 1 1 2 4 4	2	
49	20 Feb. 53	6°C.	3	0	10	0 0 0 0 0 0 0 0 1 1	0	
51	3 Mar. 53	5°C.	2	2	4	0 0 0 0 0 0 0 0 1 1	0	
52	6 Mar. 53	5°C.	5	0	10	0 0 0 0 0 0 0 0 0 2	0	
53	9 Mar. 53	6°C.	31	–	68	after one night	2	3 in. layer, 3 nights. Hosing and change of water after 1st night.
53	9 Mar. 53	6°C.	31	0	–	after two nights	0	
53	9 Mar. 53	6°C.	–	1	–	0 0 0 0 0 1 1 2 3 3	1	
54	13 Mar. 53	6°C.	0	–	30	after one night	2	
54	13 Mar. 53	6°C.	2	0	–	0 0 0 0 0 0 0 0 1 2	0	
55	16 Mar. 53	6°C.	8	–	13	after one night	0	
55	16 Mar. 53	6°C.	1	1	–	0 0 0 0 0 0 0 0 0 0	0	
56	18 Mar. 53	6°C.	11	–	38	after one night	3	
56	18 Mar. 53	6°C.	10	2	–	0 0 0 0 0 0 1 1 1 2	1	

ıpty shells and other rubbish. Untreated sea water was pumped over them and they re left over two nights. Samples of both water and mussels were taken at the start of each periment (35-38), and again at the end. The results are given in Table 7. It can be seen ıt a very substantial reduction in the bacterial content took place in each case, and,

according to the usually adopted standards for molluscan shellfish, the final prod would be acceptable in the markets. These results were not considered good enough as t were some way below the usual Conway standards. For the next two experiments (40-4 a period of three nights was adopted and seemed to yield improved results. To make for the decreased throughput a doubling of the thickness of the mussel layer was tried, the result was not encouraging—Experiment 42. A series of nine experiments follo (43-52), in which the single layer treatment for three nights with the water unchan was used. The results from all these were satisfactory. In a further four experiments (53- the water was changed after the first night of the three-night treatment. It was thou that replacing the water would renew the oxygen supply and thus encourage more vigor functioning of the mussels, and that by running the water off after one night a la proportion of the faeces would also be removed. This modification did not give significant improvement. From these experiments it was concluded that a three day tr ment without change of water would give satisfactory results with a mussel layer 3 thick and a depth of water of 3 ft.

BACTERIOLOGICAL SURVEY OF THE WATER IN THE TEIGN ESTUARY

When the Teign estuary was surveyed in 1952 water samples from different parts w examined. The results are shown in Fig. 1. The upper reaches, where the mussels

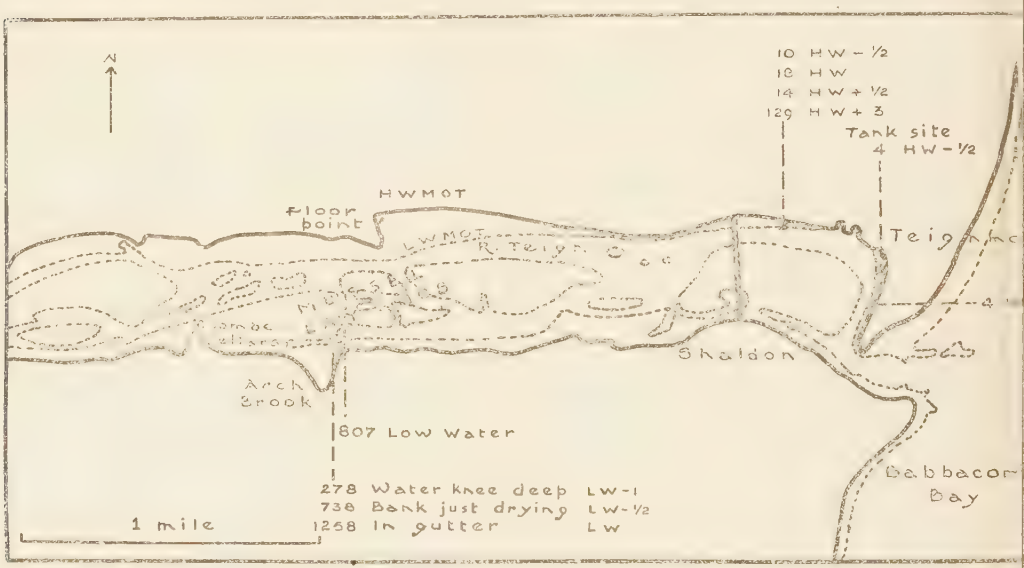

Fig. 1: *Map of Teign Estuary showing the results of bacteriological examination of w samples. For each sample the number of faecal* Bact. coli *per* 10*ml. of water is g followed by the state of the tide at the time of taking the sample.*

cultivated, were found to be heavily polluted, the pollution increasing as the tide Towards the mouth of the river pollution was less severe and towards high water almost absent. On later occasions samples were taken at the tank site at various stag the tide to determine the period during which reasonably clean water could be obta These results are given in Table 8. It was found that at low water, and for the first ho the flood, pollution was heavy, but that from two hours flood to high water it was After high water there was a tendency for the pollution from places up the river, espe Newton Abbot, to become serious; but this was not usually the case until three hou more had elapsed. On one occasion heavy pollution was encountered at $2\frac{1}{2}$ hours ebb.

Table 8: *Water samples at Teignmouth tank site*
Counts of faecal *Bact. coli* per 10 ml. of water

	11 Feb. 53	15 June 53	16 June 53	1 Oct. 53	2 Oct. 53	5 Oct. 53	6 Oct. 53	7 Oct. 53	8 Oct. 53	9 Oct. 53
Sample at H.W. — 6 hrs.	417									
— 5 hrs.	208									
— 4 hrs.	8				1	1	3		5	
— 3 hrs.	1				1	1	1		0	
— 2 hrs.	0						3		2	
— 1½ hrs.	0			5						
H.W.	0	0						2	0	2
+ 1 hr.			4							
+ 1½ hrs.		1	3					5	2	
+ 2 hrs.							2	1	1	12
+ 2½ hrs.		2,340	12				4	4		
+ 3 hrs.									3	20
+ 4 hrs.		344							15	166
+ 5 hrs.									184	91
+ 6 hrs.										362

ay well have come from one of the ships moored at the quay 50-100 yards upstream. ll samples taken between four hours before and two hours after high water showed satis-ctorily low pollution and it was decided that pumping could safely be allowed from three ours before to one hour after high water. This gave a four hour pumping period on each le and allowed a reasonable safety margin at each end.

EXPERIMENTS AT TEIGNMOUTH

In October 1952 the question of providing purification facilities at Teignmouth came
head. The work at Conway was still at an early stage but enough had been done to s

Table 9: *Experimental cleansing of mussels in boats at Teignmouth*

Date (1952)	Counts of faecal *Bact. coli* per ml. of flesh in Mussels											Description of source
	Before treatment	After treatment										
		Individuals									Pool	
31 Oct. 52	39	0	0	0	0	0	0	0	2	2	0	From upper "lays"
31 Oct. 52	38	0	0	0	0	0	0	0	0	8	2	From lower "lays"
8 Nov. 52	1	0	0	0	0	0	0	2	2	2	1	From upper "lays"
14 Nov. 52	10	0	0	0	0	0	0	0	0	0	0	From upper "lays"
14 Nov. 52	25	0	0	0	0	0	0	0	0	0	0	From lower "lays"
22 Nov. 52	108	0	0	2	2	10	16	38	114	–	23	From upper "lays"
22 Nov. 52	30	0	0	0	2	4	4	14	16	96	24	From lower "lays"
29 Nov. 52	0	0	0	0	0	0	0	0	0	0	1	From upper "lays"
6 Dec. 52	5	0	0	0	0	0	0	0	2	4	1	From upper "lays"
6 Dec. 52	3	0	0	0	0	0	0	0	0	2	0	From lower "lays"
15 Dec. 52	31	0	0	0	0	0	0	2	2	6	2	From upper "lays"
15 Dec. 52	4	0	0	0	0	0	0	2	2	2	34	From lower "lays"

*Presumably this mussel was damaged or already moribund.

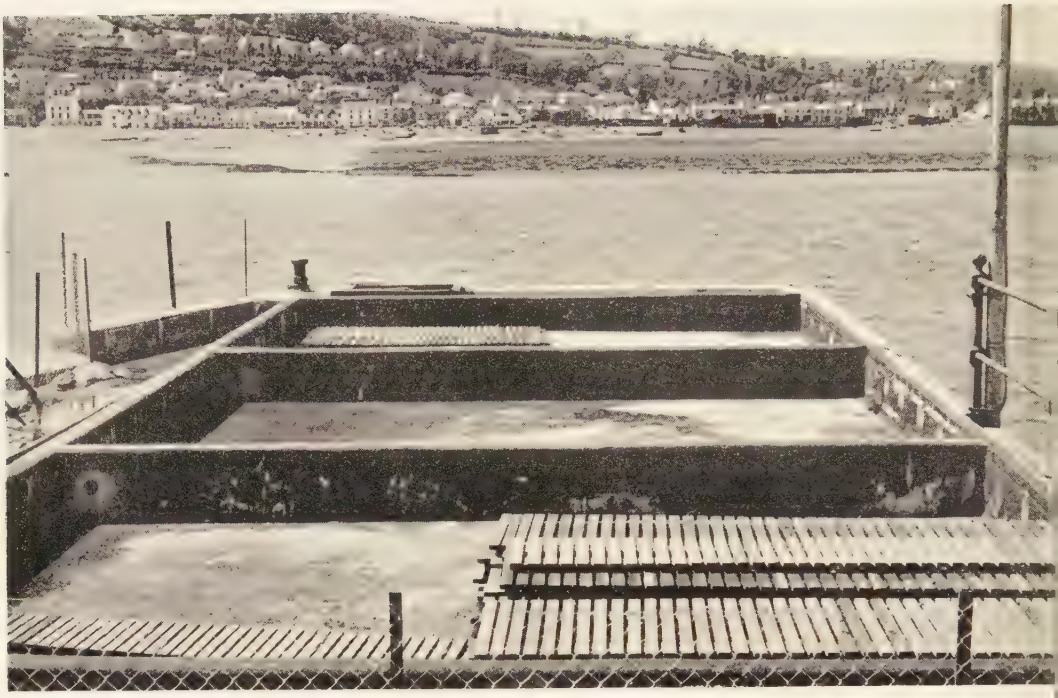

Plate 1: *Teignmouth Mussel Tank. Photograph taken at the end of the mussel season. Mos of the grids are stacked in the near section. Holes have been made in the inter-section walls t facilitate filling. The pump is housed in the compartment to the right of the bollard.*

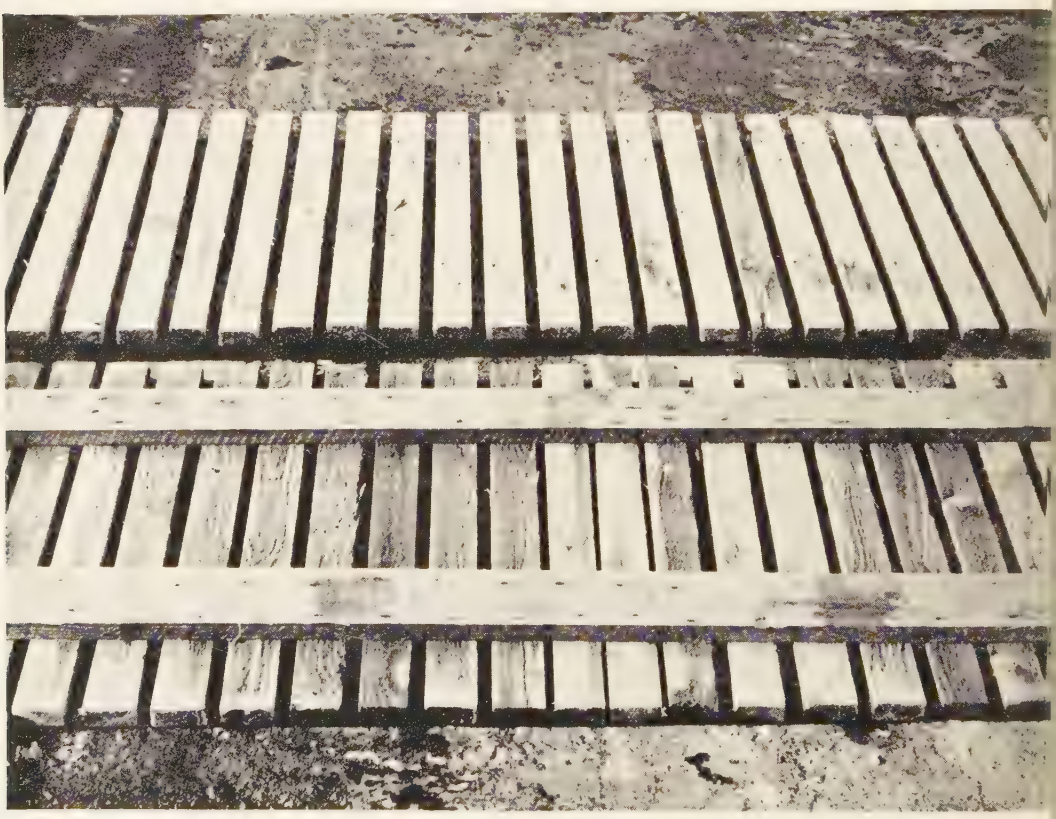

Plate 2: *Grids. The near one is turned over to show the construction.*

it the new method was promising. It was clear that if a tank was going to be built it uld have to be provided by the fishermen. This being so it was essential to demonstrate them that the methods proposed would work, and it was desirable to put the method a practical test lasting several weeks at the proposed site.

A meeting of the fishermen was held and the principles of the method were explained them. As a result of the discussion that followed, it was decided that they should purify o lots of mussels each week. A pair of rowing boats beached on the shore were to be ed as purification tanks, one for mussels from their layings in the upper part of the uary, and the other for mussels from the lower layings. For each experiment the floors the boats were to be covered with mussels in a single layer (1 mussel thick), and about in. of water were to be put over them, the water to be taken at high water. Samples of the ssels before treatment, and after three nights in the boat, were to be sent to Conway for amination. Over a period of about six weeks twelve experiments were completed. The sults are given in Table 9, and it can be seen that, apart from the experiments started on .11.52, they were highly successful. The one failure was probably due to the fact that ring the experiment some boys rocked the boats vigorously and stirred up the mud and cted faeces, thus probably causing a re-pollution of the mussels. This could not happen a mussel tank! Towards the end of the six weeks the weather was cold, with temperatures ling to freezing point, and there were several falls of snow in Devonshire, so that it is r to say that the method was given a trial under wintry conditions and there were no lications that the cold weather interfered with the treatment.

This series of experiments ended about a week before Christmas because of the risk of mples being delayed in the post at that time. Enough had been done to show that the thod was reliable, provided that outside interference could be avoided. The ability of the hermen to carry out the process was also demonstrated satisfactorily. The work involved s relatively arduous as the boats had to be filled with water by means of buckets, a long , especially as it often had to be done in the dark. The efficient way in which this was ne augured well for the future running of the tanks by the men.

THE TANK AT TEIGNMOUTH

HERE is at Teignmouth an active association, "The Teign Watermen and Fishermen's sociation"; all the men interested in mussels are members, and it was decided that it uld be best for the building, and, later, the running of the tank to be done by the sociation. The Association as a whole could not undertake to pay for it as out of the -50 members only 11 were actively interested in mussel fishing, so these eleven men rmed themselves into a Musselmen's Committee within the Association. They agreed to ntribute £10 each towards the cost initially, and later such further sums as might be cessary. This meant that they alone would have the right to use the tank, but provision s made for others to join the "Musselmen's Committee" later if they so desired.

The most suitable site was on the New Quay, and the Council willingly allowed it to used for this purpose free of charge in the first instance, but reserved the right to charge ent later on. The surface of the quay was of level concrete and it was only necessary to ild walls round a suitable area to form the tank. A size of 20 ft. × 40 ft. × 20 in. deep, s decided on, divided into three sections each 20 ft. × 13 ft. 6 in. This would accommo- te 50-60 one cwt. bags at one filling, the mussels being 3 in. deep, and, on a three day atment basis, would allow a throughput of 100 bags a week. The depth of the tank was nited by the Council in order to avoid over-weighting the quay. The walls were built of e-cast concrete blocks and the whole tank was coated inside and out with bitumen late 1). The grids, each 2 ft. × 10 ft., were made of red deal and each consists of a mber of short slats, 2 in. wide, 1 in. thick, nailed at $\frac{1}{2}$ in. intervals on to a pair of long embers. The latter rest directly on the floor (Plate 2). Water is supplied by a $\frac{3}{4}$ h.p. ctric pump which delivers 2,000 gall. per hour and fills one section of the tank in an ur and a quarter, or the whole tank in about four hours. A 4 in. outlet is provided to ch section; these are closed by drain testing plugs, which are very much cheaper than

valves. The total cost was under £200, made up approximately as follows:—buildi walls and rendering with bitumen £80, electric pump £35, intake and delivery hose wood for grids £30.

The Secretary of the Fishermen's Association agreed to act as Tank Superintende return for a small fee for each bag of mussels cleansed. The fishermen wash the mus spread them in the tanks, hose them at the end of the process and bag them up. Secretary is responsible for seeing that water is pumped only within the permitted pe he usually changes the water as required, and issues the "Purified Mussels" labels a end of the treatment. He also does most of the work of writing to prospective bu buying clean sacks in bulk and handling all the moneys connected with the sale of mus payment of transport charges, etc. The fishermen pay him 1/- for each bag of mu cleansed, and also contribute 1/- per bag to a tank maintenance fund. These pay the run costs and provide a fund for future extensions or modifications.

THE FIRST SEASON

THE mussel tank was officially opened on October 1, 1953. The first lot of mussels tr was a small one of 5 cwt., intended purely as a trial. This was successful and subseq lots were sent to market (Table 10). The mussels were brought from the beds by

Table 10: *Bacteriological results of the first four lots of mussels purified in the Teignmouth tank*

	Counts of faecal *Bact. coli* per ml. of flesh in Mussels			Remarks
	Before treatment	After treatment		
		Individuals	Pool	
Trial Lot	7	0 0 0 0 0 0 0 1 0 0	0	After 1 night
		0 0 2 0 0 0 0 0 0 0	0	After 2 nights
		0 0 0 0 0 6 0 3 0 2	1	After 3 nights
1st Commercial Lot	140	5 19 0 5 2 1 1 2 25 –	12	After 1 night
		0 0 0 0 0 2 0 1 1 0	1	After 3 nights
2nd Commercial Lot	27	0 5 0 0 1 0 1 1 1 0	1	After 1 night
		0 0 0 0 2 0 1 0 1 1	0	After 3 nights
3rd Commercial Lot	118	0 0 1 1 0 1 0 0 2 1	0	After 1 night
			0	After 3 nights

washed thoroughly in wicker baskets in the sea, and then spread on the grids in the 'This washing was effective in removing external mud. The tank was filled with sea and for the first two batches this was left on the mussels over two nights, the water was run off and fresh water pumped up for the third night. It was noticed that on the secon of the treatment the mussels were not functioning and the water became slightly cl It appeared that the water did not contain enough oxygen to last the mussels for two Since all the water samples taken during the permitted pumping period had cont

or less *Bact. coli* per 10 ml., it seemed that 24 hours was a long enough contact period for e mussels to remove the bacteria from it and commence cleansing themselves. For the ird and subsequent batches the water was changed every 24 hours and three such baths ere given. All bacteriological results were satisfactory. At the end of the treatment the ater was run off and the mussels hosed with seawater taken during the permitted pumping riod. They were then put into clean second-hand bags, the special dated label showing at they had been purified.

During the first month 117 cwt. were purified, in later months this rose to an average about 150 cwt., making a total for the first season of 753 cwt. The limiting factor was the pply of mussels. In this estuary they are all cultivated on private layings and owing to the eat difficulties of finding markets for polluted mussels in recent years, the stocks on e layings had been allowed to fall very low. The fishermen had been so encouraged by the ccess of their tank that in the autumn of 1953 they relaid over 100 tons of young mussels their beds, and it is expected that within a few years their output will be many times eater than it is now.

In the light of experience some modifications to the tank seem desirable, and are being ade as money becomes available. A supply of fresh water has been laid on, so that hosing

Table 11: *Samples from Teignmouth, examined at Conway—first season*

Lab. Ref.	Date	No. of nights treatment	Counts of faecal *Bact. coli* per ml. in Mussels After treatment										
			Individuals										Pool
2560	20 Oct.	3	0	0	0	0	0	0	0	0	0	0	0
2567	23 Oct.	1	1	2	0	0	0	0	1	0	0	0	2
2568	23 Oct.	2	0	0	3	2	1	2	0	1	2	0	0
2569	23 Oct.	3	0	0	1	0	0	0	1	0	0	0	0
2574	24 Oct.	2	0	0	0	2	2	0	0	2	0	0	0
2575	24 Oct.	3	0	4	6	0	2	2	0	0	4	2	6
2579	26 Oct.	0											75
2587	27 Oct.	2	5	0	0	0	0	2	1	1	3	2	1
2588	27 Oct.	3	0	0	1	0	0	0	2	0	5	1	1
2603	29 Oct.	3	3	0	0	5	0	1	1	7	1	–	2
2604	29 Oct.	2	0	0	0	0	0	0	0	1	2	0	0
2605	31 Oct.	3	0	0	1	0	0	0	0	0	0	0	0
2607	5 Nov.	2	1	1	0	0	1	1	0	2	0	1	1
2609	6 Nov.	3	2	0	1	0	0	6	0	0	0	0	0
2618	10 Nov.	2	0	0	1	0	0	1	1	0	0	0	0
2619	10 Nov.	3	0	0	0	1	0	0	0	0	0	1	0
2625	13 Nov.	1	0	0	1	0	5	1	0	0	1	0	1
2627	13 Nov.	2	0	0	0	0	0	0	0	0	0	0	0
2628	13 Nov.	3	0	0	0	0	0	0	0	0	0	0	0
2722	5 Jan.	0											10
2723	7 Jan.	2	0	0	0	0	0	1	0	0	0	1	1
2724	8 Jan.	3	1	0	0	0	0	0	0	0	0	0	0
2725	11 Jan.	0											11
2726	11 Jan.	2	0	3	0	0	0	0	1	0	0	0	1
2731	12 Jan.	3	0	0	0	0	0	0	0	0	0	0	0
2735	15 Jan.	3	1	0	0	0	0	0	1	0	0	0	1
2740	20 Jan.	3	0	0	1	0	0	2	0	0	0	0	0
2748	25 Jan.	3	0	0	0	0	0	1	0	0	0	0	1
2749	26 Jan.	3	0	4	3	0	0	3	0	0	0	1	0
2755	2 Feb.	3	0	0	0	1	1	0	1	0	0	0	1
2768	13 Feb.	0											16
2779	16 Feb.	2	1	1	2	1	0	5	0	1	8	1	1
2780	16 Feb.	3	4	0	0	0	1	2	9	0	1	2	2
2794	25 Feb.	3	0	0	0	0	1	0	0	10	0	–	2
2807	27 Feb.	2	0	1	0	0	0	0	0	0	0	0	0
2808	27 Feb.	3	1	0	0	0	0	0	0	0	0	0	0
2817	4 Mar.	2	0	0	0	0	0	1	0	0	0	1	0
2824	5 Mar.	3	0	0	0	0	0	1	0	0	0	0	0

may be done irrespective of the state of the tide. This will be a great advantage on d when the tide is ebbing in the morning at the time when it is desired to take the mus out. A sloping floor has been fitted to one section to make it easier to wash it down this will probably be extended to the other sections later. A larger pump would proba have been an advantage, the size was limited by the amount of money available.

During the first season 32 samples of purified mussels were examined at Conway, with satisfactory results (Table 11). A number of samples were also examined at the Pu Health Laboratory at Exeter, for the Ministry of Health, with equally satisfactory resu As a direct result of the establishing of this mussel tank the City of Birmingham has w drawn its Order prohibiting the entry of Teignmouth mussels into Birmingham mar and the Fishmongers' Company of London have agreed to allow them into Billingsgate the first time for many years.

ACKNOWLEDGMENTS

ALL the water samples taken at Teignmouth and some of the mussel samples w examined in the N.A.A.S. Laboratory at Staplake Mount, Starcross, and I wish to exp my gratitude to Miss M. A. Edwards for so willingly providing facilities and assistance.

SUMMARY

FACTORS affecting the purification of mussels in a limited volume of water were exami in turn and it was found that:

(*a*) The tank did not need to be flushed out between batches of mussels.

(*b*) Mud on the mussels did not prevent purification.

(*c*) Grids were not necessary for purification but facilitated the final hosing.

(*d*) Mussels could be purified in a layer 3 in. thick, but a 6 in. layer was not alw satisfactory.

(*e*) A fresh lot of water was needed for each batch of mussels. A depth of water of was needed for the continuous functioning of a 3 in. layer of mussels for 48 hour

(*f*) A single 48-hour bath gave satisfactory results at temperatures from 1°C. u about 15°C. with initial water pollutions up to 30 faecal *Bact. coli* per 10 ml.

These principles were applied in the tank built and run by the fishermen at Teignmo Because of the nature of the site the depth was limited to 2 ft., which necessitated changing of the water every 24 hours. The mussels were washed in baskets in the sea given three 24-hour baths in the tank in seawater taken on the incoming tide. They v then hosed and packed in clean sacks for market. All bacteriological results have b satisfactory.

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